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On the recommendation of the Council, it was—

Resolved,—1. That attendance at the Stated Meetings of the Committee of Publication, as prescribed by the resolution of February 27, 1860, shall reckon as attendance at the Meetings of the Council.

2. That the sum of £50 be placed in the hands of the Council for the purchase of antiquities for the Academy's Museum.

Captain A. T. Blakely, R. A., read a paper—

ON THE PRACTICAL APPLICATION OF A PRINCIPLE ANNOUNCED TO THE ACADEMY BY R. MALLET, ESQ.; AND SOME REMARKS ON RIFLED CANNON.

For at least two centuries the advantages of cutting spiral grooves in the inside of the barrels of small-arms has been known, although we possess no record to prove that the reason for it was understood until Mr. Robins investigated the subject, about 100 years ago. That gentleman not only explained how the resistance of the atmosphere retarded the flight of projectiles, and its friction deflected them from their expected course, and how the latter evil was lessened by "rifling" the barrel, thus giving the projectile a rotation about an axis parallel to that of the gun; but he also distinctly pointed out the gain in range to be obtained by using elongated shot. He died before completing his experiments; and, until about the year 1823, no progress seems to have been made in that direction, though I have no doubt that the subject was investigated during the interim, and that at this very moment many of those investigations could be found on the shelves of a certain public office, neatly tied up with red tape, and most correctly labelled.

In 1823, Captain Norton, of the 34th Regiment, began to fire elongated bullets, and he soon overcame those unexpected difficulties which meet the first experimenter in every branch of science. His success was unfortunate for himself, and useless to his country, which only acknowledged the justice of his views after Messrs. Delvigne and Minié had worked out the problem for the French Government.

The advantage of an elongated projectile obviously is, that the air has a less surface to resist than if the same weight of bullet were in a spherical form, and that, consequently, less velocity is lost in passing a given distance through the atmosphere. The disadvantage is, that the long bullet leaves the barrel with a less initial velocity the longer it is in proportion to its diameter, because the gas of the gunpowder has a less surface to press against.

It is evident that for every range there will be a particular form of bullet better suited than others, and that the very long bullet necessary to hit a target 1200 yards off may be ill suited to shoot a living object 300 yards distant, as this would have time to move after seeing the flash of the rifle before the slow-moving bullet reached them. Sportsmen have abandoned very long bullets, after a fair trial of them. Public opinion is now attempting to force their use on the army.

It seems strange, at first sight, that cannon were not earlier and more extensively rifled than they were. The reason is not obvious, why large bullets from large rifles should not give results proportionate to those obtained from small bullets and small rifles. Colonel Cavalli, the able Superintendent of the Sardinian cannon factory, was one of the first who grappled with the difficulty. He found, however, that if he used more than a very moderate charge of gunpowder, his cannon burst. Mr. Lancaster's experience might be stated in the same words. Mr. Joseph Whitworth, perhaps the most successful mechanical engineer who ever lived, after rifling some small cannon, which projected bullets with accuracy almost incredible, rifled one with a bore of about four inches, and sides nine inches thick. It burst. He tried one with sides eleven and a half inches thick. It, too, burst.

Mr. Bashley Britten, in 1854, discovered a very simple method of attaching lead to an iron shot by soldering. His projectile enters a cannon easily from the muzzle, and, on the ignition of the gunpowder, the lead is forced by the gas to fill the grooved barrel, and give the projectile the necessary "spin." With such shells, Mr. Britten has obtained results from old-fashioned cannon far beyond all competition. He has rifled several service 32-pounders, and fired 51 lb. shells from them, getting a range of upwards of two miles with 10° of elevation, using 6 lbs. of gunpowder. From service 18-pounders he could fire 28 lb. shells with 4 lbs. of gunpowder, getting excellent ranges. He tried some 34 lb. shells and 6½ lbs. of powder, and the gun burst. Many others tried, and minor obstacles were overcome. Either by loading at the breech, or by using expanding bullets like Mr. Britten's, windage was avoided; by coating the bullet with lead, or by planing it, excessive wear and tear of barrel was prevented; but progress was barred by the difficulty of obtaining cannon of sufficient strength to bear charges of powder proportionate to the weight of projectile, until that principle of construction was adopted which was first publicly advocated in this room by Mr. Robert Mallet on the 25th of June, 1855. As the reasoning of Mr. Mallet, and Dr. Hart's calculations, are to be found in the Transactions of this Academy, I will only briefly remind you that they recommended cannon to be built up tube over tube, each tube compressing those within it to a degree to be exactly determined by previous calculation. This compression of the inner tubes, and consequent extension of the outer tubes, is necessary, they argued, to prevent the inside breaking before communicating sufficient strain to the outside, as is the case in any thick tubes made in one piece. My object in addressing you this evening is to mention some facts which will corroborate these views.

Table A gives the dimensions of some cylinders when strained from within, as obtained by actual measurement by Major Wade, of the U. S. Ordnance. With every degree of strain, it will be observed, the outer portions of these cylinders stretched less than the inner ones, and that, too, in a greater ratio than any of the received formulæ would account for. Major Wade also burst some cannon for his Government by water-pressure, and found their strength to resist pressure from within, in some cases, only one-quarter what it would have been had the whole thickness shared equally in resistance.

TABLE A.—*Extension of Hollow Cylinders.*

CYLINDER No. 1.

Force applied.	Diameters in Inches.		Ratio of Increment to the original Diameters.		Outside less stretched than Inside.	Thickness of Metal.	Area of Cross Section.
	Interior.	Exterior.	Interior.	Exterior.			
lbs.							Sq. Inches.
0,000	·8050	1·3090	One in	One in	As one to	·2520	·83681
1,000	·8061	1·3093	732	4,367	$5\frac{4}{10}$	·2516	·83603
2,000	·8083	1·3100	277	1,309	$4\frac{3}{4}$	·25085	·83468
3,000	·8102	1·3110	155	655	$4\frac{1}{4}$	·25040	·83432
4,000	·8114	1·3120	126	437	$3\frac{1}{2}$	·25030	·83486
5,000	·8126	1·3130	107	327	$3\frac{1}{16}$	·25020	·83439
6,000	·8141	1·3140	88	262	3	·24995	·83554
7,000	·8153	1·3150	78	218	$2\frac{8}{10}$	·24985	·83607
					Average $3\frac{1}{2}$		
CYLINDER No. 2.							
0,000	·8030	1·812	....	....	....	·5045	2·0723
5,000	·8030	1·812	....	....	....	·5045	2·0723
8,000	·8053	1·813	349	1,812	$5\frac{1}{5}$	·50385	2·0722
10,000	·8067	1·814	217	906	$4\frac{1}{5}$	·50365	2·0733
12,000	·8085	1·815	146	604	$4\frac{1}{7}$	·50325	2·0739
14,000	·8110	1·816	100	453	$4\frac{1}{2}$	·50250	2·0736
					Average $4\frac{1}{2}$		
CYLINDER No. 3.							
0,000	·8100	1·8120	....	....	....	·50100	2·0635
5,000	·8100	1·8120	....	....	....	·50100	2·0635
8,000	·8124	1·8127	337	2,588	$7\frac{2}{3}$	·50015	2·0624
10,000	·8137	1·8130	219	1,812	$8\frac{1}{4}$	·49965	2·0616
12,000	·8151	1·8134	159	1,294	$8\frac{1}{7}$	·49915	2·0609
14,000	·8171	1·8140	114	906	8	·49845	2·0600
					Average $8\frac{1}{2}$		
CYLINDER No. 4.							
0,000	·8070	1·811	....	....	....	·50200	2·0644
5,000	·8124	1·812	149	1,811	$12\frac{1}{7}$	·49980	2·0604
8,000	·8166	1·814	84	604	$7\frac{1}{5}$	·49870	2·0606
10,000	·8177	1·814	75	604	8	·49815	2·0523
12,000	·8205	1·815	59	453	$7\frac{2}{3}$	·49725	2·0585
14,000	·8211	1·815	57	443	$7\frac{3}{4}$	·49695	2·0578
					Average $8\frac{1}{2}$		

To show how rapidly the resistance of the metal in tubes diminishes from the centre, even using Professor Barlow's formula, which makes the resistance inversely as the square of distance from the centre, I have made out a Table (B) of what force each successive annular inch can exert in a cannon 4 inches in bore and 10 inches thick. The strength of each ring being 1000, the numbers in the Table show the portion of their strength which they can use. The total strength of such a tube, it will be remembered, is only one-sixth what it would be if the strain were equally distributed.

TABLE B.—*Force exerted by successive layers of Metal in a Cylinder* 4 *inches inner diameter and* 10 *inches thick, the strain on the inner film being* 1000.

		Force which could be exerted, were the inner 4 inches removed.
Inside annular inch, . . .	666	. . . .
Second ,, ,, . . .	333	. . . .
Third ,, ,, . . .	200	. . . .
Fourth ,, ,, . . .	133	. . . .
Fifth ,, ,, . . .	96	857
Sixth ,, ,, . . .	70	643
Seventh ,, ,, . . .	55	500
Eighth ,, ,, . . .	44	400
Ninth ,, ,, . . .	36	327
Tenth ,, ,, . . .	30	253
Total, ...	1663	3000

Theory gives the third inch a power of exerting one-fifth of its strength. A reference to Table A shows that Major Wade's actual measurements gave only half even of this.

Paradoxical though it may seem, a thick tube like this would be much strengthened by diminishing its thickness.

Professor Barlow's formula would give 6 inches as the thickness of maximum strength for a tube of the outer diameter of the one we have been considering. Its strength then would be 3000, or nearly double that of the thicker tube, because, the four inner rings being removed, the others could use more of their strength. Yet the Government is to this day making cannon with bores of 6 inches, and walls of nearly 12. I have said enough (I hope not too much) about the weakness of cannon made in one mass. It remains for me to record what has been done to prove *practically* the advantage of making them of concentric laminæ.

In February, 1855, I made an 18-pounder cannon of a cast-iron gas-pipe, with two layers of wrought-iron hoops shrunk on it. It was so strong that I afterwards had it bored out to the diameter of a 24-

pounder. It was then 2½ inches thick at the strongest part, yet it bore being fired with 4 lbs., 5 lbs., 6 lbs., 7 lbs., and ultimately several times with 8 lbs. of powder, and a 24-pound shot.

In May, 1855, I altered an ordinary cannon, cutting away some of the useless outside part, and replacing it with metal, put on with initial tension. This was a most satisfactory experiment, for an unaltered cannon of cast-iron, of the same size and weight, and one of brass, were tried against it. All three were fired 68 times with one charge of powder and one shot; 26 times, 1⅓ charge, 1 shot; 5 times, 1⅓ charge, 1 shot; 5 times, 1⅓ charge, 2 shots; 110 times, 2 charges, 2 shots.

The cast-iron gun here burst at this round. Firing was continued from the brass gun and mine, 74 rounds more, with double charges of powder and 2 shots, when the brass gun was found to have utterly lost its shape. After the destruction of both its rivals, 134 rounds more were fired from my gun with the same charge; then double charges of powder, and 3, 4, and 5 shots were tried, till the barrel was filled. It was fired 158 times with a double charge of powder, and crammed to the muzzle with bullets. Although these two guns and three others were finished by me before Mr. Mallet read his paper here, yet I had taken such precautions to keep my proceedings secret (as we were engaged in war with Russia at the time) that it is utterly impossible he could have learned anything from me.

In the spring of 1855 Mr. James Longridge, a civil engineer, noted for his mathematical skill, arrived at the same conclusion as Mr. Mallet, Dr. Hart, and myself. He put them into practice by making a 9-pounder gun of a thin iron tube, with wire wound round it with an accurately measured tension. This is, doubtless, the way to make the strongest possible tube from a given quantity of metal, and will, I expect, be found of great value in the construction of monster mortars. Next in point of date comes the French naval rifled cannon, adopted in 1858. It is made only in two layers, the inner of cast-iron, and in one piece; the outer one of wrought iron, and in five pieces. About the same time Colonel Cavalli commenced to make his breech-loading cannon in two layers also, the inner tube being of brass, but short, extending only round the seat of the charge, and a few inches in front of it. The rest of his guns are of cast-iron. In 1859 the celebrated Armstrong gun was adopted into the military service of this country. It, too, is built up. The inner layer is made by twisting bars of iron into coils, welding each coil into a short cylinder, and then welding those cylinders together end to end. The next layer is made by welding together lengthways two long pieces, semi-cylindrical in section; the third layer is made of coils, like the first, but these are not welded to each other. I should observe that Sir W. Armstrong disclaims most distinctly any desire to obtain strength by adjusting the size of the different layers, and although I talked over with him the theory advanced by Mr. Mallet and myself some months before he brought forward his present gun, yet he learned nothing from Mr. Mallet or myself; and if he puts the tubes together with the requisite degree of tension, he does so by pure accident.

Last year Mr. Whitworth, taught by his previous failure, and rightly attributing the success of the Armstrong gun to *its strength,* himself adopted the same principle of construction for his 80-pounder gun. This he made of a tube of what he calls homogeneous iron, and tapering slightly outside. On this conical tube he forced short tubes of wrought-iron, and over these a third layer of tubes. This method of putting tubes together is, I think, much better than that used by the French Government and by Sir William Armstrong, who heat the outer tubes and allow them to shrink on the inner ones.

Within the last few months Sir W. Armstrong has attempted an imitation of my 1855 gun for our navy. His new naval guns are 6½ inches in bore. The interior is of cast-iron, about 6 inches thick from the breech to just behind the terminus, where the thickness is suddenly increased to 8½ inches. I need hardly say they must break at this point. The weight is 98 cwt., and they cannot be depended on to fire the 70 lb. shells for which they were constructed. I mention them to point out the real cause of failure, which has been wrongly attributed to the circumferential strength obtained by the double layer of metal at the breech being sufficient. To rebut this, I need only say that a 10-inch gun built up of only two layers, but of better proportions, stood 10 rounds with 20 lbs. powder and 132-pound shot; 10 rounds with 20 lbs. powder and 264 lb. bolt; 10 rounds with 20 lbs. powder and 396-pound bolt; 9 rounds with 20 lbs. powder and 512-pound bolt.

That gun, though LIGHTER THAN THE NEW NAVAL GUN BY HALF A TON, would never have burst with 70 lb. shells!

I last year made a gun something like this in form, and only half the weight of the new naval gun, 48 cwt. instead of 98. From it I have thrown 58 lb. shells with a greater velocity than such shells have ever before been thrown. One of my objects in making this gun was to prove that the efficiency of a rifled cannon depended principally on its strength—strength which has yet been obtained in one way *only*—for cannon of any size, viz., by building them up in *at least* two layers. I fired Mr. Bashley Britten's shells, already described, and obtained such great velocity that they flew above a mile and a half (2670 yards) with only 5° elevation. It is but a short time since Sir W. Armstrong thought it much to do this with double the elevation. The range of Mr. Whitworth's 80-pounder, solid shot, with 5° elevation, is reported to have been less than that of the 58 lb. hollow shells I fired, but, as the wind may have favoured me, I have invited him to a friendly trial of our respective guns at the same time and place.

I have now endeavoured to show that no rifled cannon of considerable size have succeeded when made in one mass; that all French, Sardinian, Armstrong, Whitworth, and my own, have succeeded when built up, all except the new naval gun, which fails from obvious causes; and, lastly, that the success of successful rifled cannon has been due neither to their having thirty-six grooves, nor to their being polygonal in section, but to their *strength.*

DR. HART'S REMARKS, MADE AFTER THE READING OF CAPTAIN BLAKELY'S PAPER.*

Dr. Hart having been called on by Professor Haughton for an account of his investigations, said that his attention had been directed to the subject by Mr. Mallet, who, about the year 1854,† asked his opinion on a mechanical question, which he represented as an application of the principle of the lever to a cylinder by surrounding it with a series of blocks of a considerable thickness, and fastening on a hoop outside these blocks. Having expressed his dissent from this idea of converting such blocks into levers, he was reminded of the well-known fact, that, when a cylinder is submitted to a strong internal pressure the inner surface is more strained than the outer, and consequently yields, and is split before the outer surface has borne any considerable portion of the strain. Now, it is obvious that this inequality of strain depends on the ratio of the inner and outer diameters of the cylinder, and, therefore, that Mr. Mallet's outer hoop, being considered as a cylinder whose thickness bore a small ration to its diameter, would be more uniformly strained, and, therefore, stronger than it would have been if applied directly without the intervention of blocks.

As it appeared, however, that this construction would add so enormously to the weight of a gun as to render it quite unsuitable for the purpose of the Russian war, Dr. Hart endeavoured to find some other mode of equalizing the strain without introducing these large blocks, which merely transmitted the force, without bearing any part of it themselves.

The obvious suggestion of using concentric cylinders of materials which differed in elastic qualities having been rejected by Mr. Mallet, the next idea that occurred was that of fitting on successive cylinders of iron with different degrees of initial tension, so calculated that when the internal strain approached the bursting point, all portions of the cylinder should be equally strained.

Mr. Mallet having at once admitted the validity of this principle, Dr. Hart gave him a calculation of the requisite amounts of initial strain, deduced from a formula which was afterwards published by Mr. Mallet in the Transactions of the Academy; and it was believed to be in conformity with this suggestion that Mr. Mallet's monster mortar was constructed.

It is said, however, that there are many practical difficulties in the way of applying this principle of construction with the requisite accuracy, and that it is liable to lose its initial tensions by time, and by repeated shocks; and it, therefore, seems highly important that Mr. Mallet's original suggestion should not be neglected. The objection of weight, although conclusive against its application to field artillery, would probably be of no importance in the case of a fixed battery. The principle of this construction is sufficiently explained by one of Captain

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* [These remarks, as also those at p. 324, are printed from a memorandum furnished by Dr. Hart.—Ed.]

† [We are requested by Dr. Hart to say, that he did not correctly state the date of this communication. It was made to him, not in 1854, but in the spring of 1855.—Ed.]

Blakely's diagrams, in which it is shown that the removal of some of the inner rings would add largely to the total strength; it is to be observed, however, that this removal of inner rings would also add in a still higher ratio to the interior diameter, and that the pressure which is proportional to this diameter would be increased more than the strength; but if the space now occupied by these inner rings was accurately filled by longitudinal bars or voussoirs analogous to Mr. Mallet's blocks, the inner diameter would be restored to its former magnitude, while the increased strength resulting from equalization of tension would be retained.

Robert Mallet, C.E., F.R.S., made some remarks on Major Blakely's paper.*

CAPTAIN BLAKELY'S REPLY.†

MR. CHAIRMAN,—I regret that the time of the Academy has been taken up this evening in hearing a discussion on a question which must be quite without interest for it,—that of the priority of discovery by Dr. Hart or myself of the method now almost universally adopted for making cannon. About three years ago, to the best of my recollection, I first heard of Dr. Hart's investigation; and, although two years had then elapsed since my actually making several cannons on the system in question, and the mortars made by Mr. Mallet on Dr. Hart's suggestions had not even then been fired, yet, hearing it stated that Dr. Hart had proposed the system before I did, I wrote to ask him whether this was or not so. I mentioned to him when I had discovered the thing, when I had first urged Government to try it, and when I had myself put it into practice. Dr. Hart's reply was, that he had not turned his attention to the matter till some months after I had actually made the guns. Not only, Sir, did Dr. Hart tell me this, but Mr. Mallet coroborated what he said. The date then given for Dr. Hart's discovery was, I think, July, 1855. If the date given to-night, namely, "early in 1854," is correct, he was in the field before me, and I shall cheerfully acknowledge that he was so, if on further reflection he is of opinion that, when the circumstances were recent, he was mistaken, and that he can now remember them enough to correct his mistake. This matter Dr. Hart alone can decide; I hope he will do so. I think, Sir, that, having finally communicated with him and Mr. Mallet on the subject of priority, and having received definitive confirmation from both three years ago, I have reason to be much surprised at the tone of Mr. Mallet's remarks to-night, from which it would be difficult to gather that, if I entertained mistaken notions about priority, I did so in consequence of having been misled by himself. In my paper to-night, I distinctly acknowledged that the principle was first *publicly* advocated in this room by Mr. Mallet in June, 1855. So much for priority of discovery and priority of publication: I shall be quite content to have carried out the system in practice on several cannon, not only years before Mr. Mallet made his mortar, but months before he read his paper here. I made guns in March, 1855; he talked of them in June of the same year.

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* [Mr. Mallet was unable, through absence, to furnish any memorandum of his remarks, which are, however, contained in his subsequent communication (June 11) to the Academy.—ED.]

† [This reply is here printed from a memorandum furnished by Captain Blakely.—ED.]

FURTHER REMARKS BY DR. HART.

A question of priority having arisen, and Captain Blakely having referred to a letter of Dr. Hart to him, in which he mentioned 1855 as the date of his investigations, Dr. Hart replied, that he had not intended to raise any question of priority; that in the letter referred to, he had said that he believed his investigations and Captain Blakely's had been simultaneous, as they were certainly independent, and that he had preserved no record of dates; but that Mr. Mallet, being in possession of the original letters which contained his calculations, could supply them if they were considered important. The fact was, that Captain Blakely's investigations were experimental, and resulted in a gun; Dr. Hart's were mathematical, and resulted in a formula. Both are presumed to be original; at all events they were distinct, and the question of priority or synchronism seems perfectly immaterial.

MONDAY, MAY 28, 1860.

Gilbert Sanders, Esq., in the Chair.

Mr. George J. Stoney read a paper "On the Propagation of Waves."

Mr. David Moore, Curator of the Royal Dublin Society's Botanic Garden, Glasnevin, read the following—

RESULTS OF FARTHER PHYSIOLOGICAL EXPERIMENTS ON THE FORMATION OF WOOD IN DICOTYLEDONOUS PLANTS, MADE IN THE ROYAL DUBLIN SOCIETY'S BOTANIC GARDEN BETWEEN THE YEARS 1851 AND 1860.

In the year 1851 I had the honour to make known to the Academy the results of a series of physiological experiments which had then been made in the Botanic Garden, with a view to ascertain the nature of the formation of wood in dicotyledonous plants, which I detailed in a paper published in the "Proceedings" of the Academy, vol. v. p. 1. Those experiments had extended over twelve years (from 1839 to 1851), and were only in a progressive state at the time the paper was read. The object of the present communication is, therefore, to state some further results, which have been ascertained since that time, and also to notice other experiments of a different kind, though made for the same purpose, during the interval between 1851 and 1860.

On reference to the paper I have alluded to, it will be found the principal experiment made was on the bole of a large tree, nearly five feet in circumference, which was bored at right angles through the centre, each bore being seven inches wide,—thus occupying half the space of the circumference of the tree, which was then left standing on four pillars of wood, occupying the other half. The whole of the wood portion soon became dead, and served only the purpose of acting as supports for the bole, without any of the functions of vitality being carried on through its medium: consequently, the bark covering the pillars of dead wood were the only parts in that portion of the tree where